Earth Science Enterprise Technology Planning Workshop

Laser Technology

James Spinhirne (GSFC), Co-Chair
Upendra Singh (LaRC) Co-Chair
Robert Menzies, Facilitator

January 23-24, 2001

Agenda

Tuesday, JAN 23, 2001

• Laser Altimetry for Earth surface Vegetation	David Harding - NASA/GSFC
• Global Carbon Cycle: sources and sinks	Donald J. Wuebbles - U. Illinois
• Tropospheric Water vapor and Ozone Measurement	Syed Ismail - NASA/LaRC
• Space-based Measurements of Tropospheric winds	Dave Emmitt - Simpson Weather Associates
• Laser Design and Requirements for Space	Robert Afzal - NASA/GSFC
• Advanced Solid State Laser Technologies	T.Y. Fan - MIT
• Advanced Solid-State Lasers for Water Vapor, Ozone Wind, and Carbon Dioxide Measurements	Norm Barnes - NASA/LaRC
• Solid State Laser Technologies and Challenges	Mark Kushina - CEO
• Jirong Yu - NASA/LaRC	
• Jim Abshire - NASA/GSFC	
• Dahv Kliner - Sandia Natl. Lab	
• Guerman Pasmanik - Passat Ltd.	
• John Degnan - NASA/GSFC	
• Laser/Lidar Technology Roadmap and Validation	Frank Peri – ESTO

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Agenda

Wednesday, JAN 24, 2001

- Identify convergence of Science needs and candidate Technology approaches
  - new capabilities enabled
  - reductions in implementation and life-cycle costs
- Define specific capability/technology needs for each measurement class
- Describe and illustrate the current state of the art for the technology
- Itemize the major technology components and current technology readiness level
- Identify ongoing investments
- Identify technology development gaps
- Delineate core technology development and risk reduction plan
- Emphasize laser transmitter subsystem development to EM-level for risk reduction purposes
- Identify schedule and cost data for brassboard and engineering model development of laser subsystems for science-driven missions
  - Show key laser technology classes needed for science mission types
  - Identify laser transmitter parameters required
    - Associate schedule and cost estimates for brassboard/EM development/testing
- Summary Plenary Session
  - 10-minute presentations by Chairs of each Breakout Session

Workshop Participants

- G.D. Emmitt SWA/UVA
- Syed Ismail LaRC
- Brad Greeley Orbital
- Dahv Kliner Sandia Nat'l Labs
- Bruce Gentry GSFC
- John Degnan GSFC
- Guermam Pasmanik Passat Ltd.
- Joanne Hopkins SRI Int'l
- Ben Barker LaRC
- John Burris GSFC
- Floyd Hovis Fibertek
- Tony Gril (?) ESTO
- Charles F. Bruce MIT Lincoln Lab
- T.Y. Fan MIT Lincoln Lab
- Renny Fields Aerospace Corp
- Robert Afzel GSFC/
- Brenda S. Smith NMOC/Stennis SC
- Alex Dudelzak Canadian Space Agency
- Stan Schneidet NPOESS/NASA
- Brian Killough NASA LaRc
- Jeff Mirick NIMA/ATTR
- Bob Schutz U of TX
- Lou DeMaio GSFC

- Brad Haughey Orbital
- Upendra N. Singh LaRc
- Robert T. Menzies JPL
- James Spinhirne GSFC
- Mark Kishina Cutting Edge

- Douglas Comer CSRM
- Bill Burt TRW
- Don Wuebbles U of IL
- David Olson ITT
- William Edwards LaRC
- Jirong Yu LaRC
- Jim Abshire GSFC
- Tom McGee GSFC
- Prabharar Misra Nat'l Academy of Science

- Bill Heaps GSFC
- John Brock TRW
- Marc A. Mogavero Northrop
- Norman Barnes LaRC
- Michael J.Kavaya LaRC
- Timothy D. Cole APL
- Ron Ticker NASA HQ

Laser Technology

Component Technologies

Quasi-CW Laser Diode Arrays
- High power (~200 W) conduction-cooled
- High brightness, high temperature LDA's
- High electrical-to-optical efficiency
- 5-years lifetime

Robust Optical Components and Coatings
- High damage threshold
- Thermal and Radiation Tolerance

Heat Pipe Technologies for Thermal Management

Efficient Long-life Driver Electronics

Measurement Approach
- Scanning Lidar Altimetry
- Differential Absorption Lidar
- Doppler Lidar

Science Needs
- Ice sheet and terrain monitoring
- Biomass Measurement
- Tropospheric Chemistry
- Tropospheric Winds
- Global Carbon Dioxide
- Cloud/Aerosol Radiative Forcing

Development Plans for Altimetry Laser Transmitter

Laser Type

- Nd:YAG high PRF (>1000 Hz),
  - Single mode,
  - Narrow frequency,
  - 5-20 Watts Output
- Micro-chip or fiber laser alternative
  - PRF>10 kHz
- 3-5 years lifetime
- Wavelength: not critical, ideally near-IR

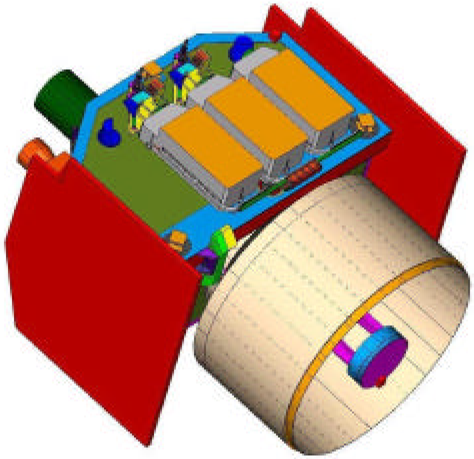
Justification

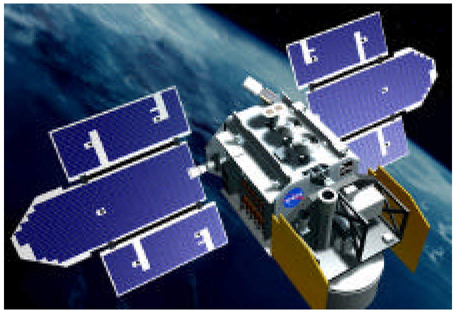
- Enables scanning altimetry lidar
  - Ice Sheet Change
  - Vegetation Recovery
  - Terrain Mapping
  - Cloud/Aerosol Height Profiling

Top-Level Development and Schedule

- Component development 2002-2003
  Brassboard 2003-2004
  Engineering Model 2004-2006


GLAS Nd:YAG Laser





Development Plans for Tropospheric Chemistry Laser Transmitters

Laser Type

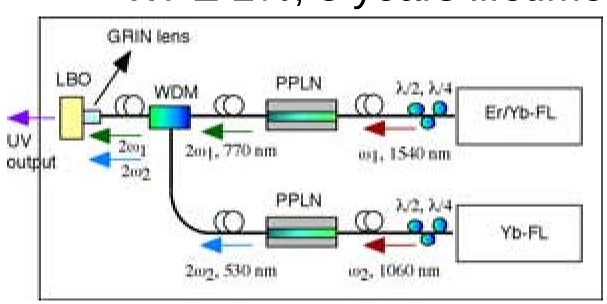
- UV Ozone DIAL
  - 305/320 nm wavelength pair
  - 0.5-1J at 5-20 Hz doubled pulse
  - 50 pm linewidth
  - WPE 1%, 3 years lifetime
- IR Ozone DIAL
  - 9.5 micron CO2 laser
  - 250 mJ @ 100 Hz
  - Frequency agile
  - WPE 15%, 3 years lifetime
- IR Water Vapor DIAL
  - 940 or 1100 nm tunable wavelength pair
  - 0.5-1J at 10 Hz doubled pulse
  - 0.25 pm linewidth,
  - Spectral purity > 99%
  - WPE 2%, 3 years lifetime

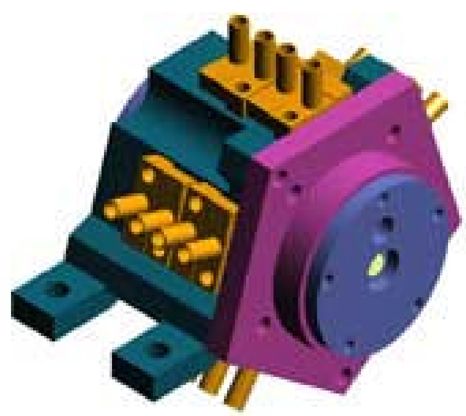
Justification

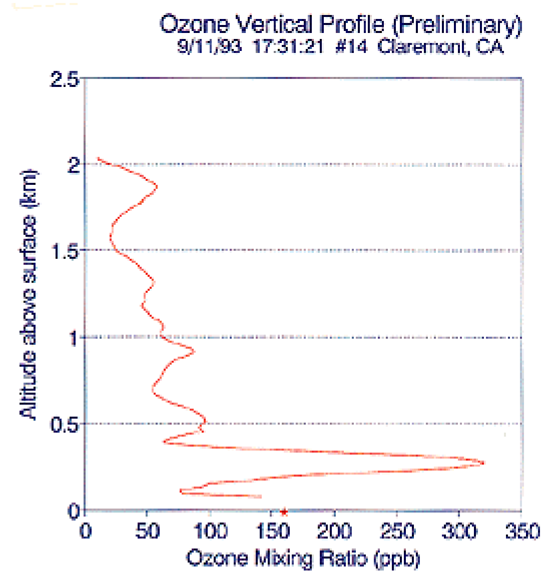
- Enables high vertical resolution profiling of
  - Tropospheric Ozone
  - Tropospheric Water Vapor

Top-Level Development Schedule

- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006



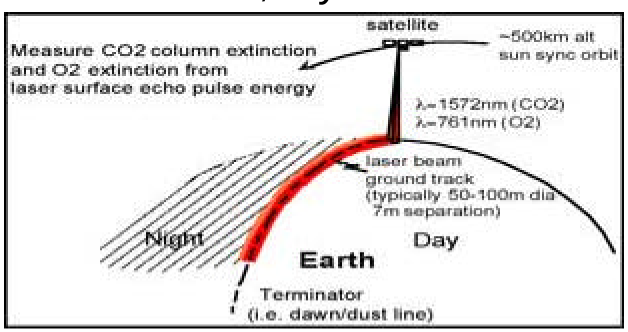




Development Plans for Tropospheric Carbon Dioxide Laser Transmitters

Laser Type

- Integrated Path Differential Absorption (IPDA)
  - 1.6 µm wavelength pair, tunable
  - "Reference" transmitter at 761 nm (1 mJ)
  - 10 mJ at 4 kHz, 1-10 microsec pulsewidth
  - 3 MHz linewidth
  - WPE 8% (goal), 3 years lifetime
- Integrated Path Differential Absorption (IPDA)
  - 2.05 µm wavelength pair, tunable
  - 3-5 W CW ; 3 MHz linewidth
  - WPE 3%, 3 years lifetime
- DIAL
  - 2.05 µm, tunable wavelength pair
  - 1-2 J at 5-20 Hz, double-pulse
  - conductive-cooling
  - 3 MHz linewidth
  - WPE 2%, 3 years lifetime



Justification

- Enables ultra high precision profiling of tropospheric carbon dioxide:
  - IPDA with tunability achieves 2-3 km vertical resolution in lower troposphere
  - DIAL with range-gating achieves 1 km vertical resolution in lower troposphere and inherent cloud/aerosol profiling

Top-Level Development Schedule

IPDA Approaches:

- Component development 2002
- Brassboard 2003
- Engineering Model 2003-2004

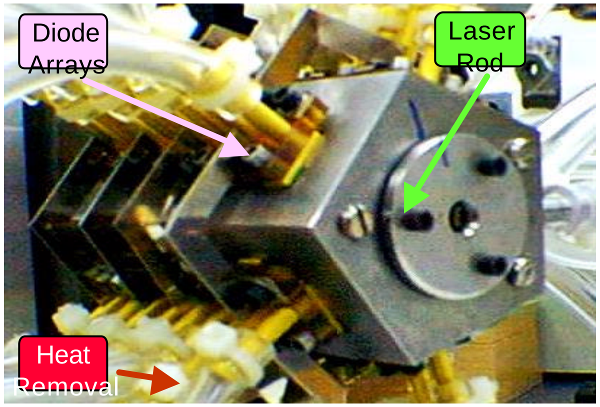
DIAL:

- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006

Development Plans for Tropospheric Winds Laser Transmitters

Laser Type

- Coherent Detection Lidar
  - 2.05 µm transmitter , injection-seeded
  - Frequency-agile LO (CW, 20 mW)
  - 0.5 J at 10-20 Hz, with conductive cooling
  - 2 MHz linewidth
  - 150-300 nsec pulsewidth
  - WPE 2%, 3 years lifetime
- Direct Detection Lidar
  - 355 nm transmitter (Nd laser, frequency tripled)
  - 300-500 mJ @ 100 Hz
  - 250 MHz (0.1 pm) linewidth
  - > 5 nsec pulsewidth
  - WPE 2%, 3 years lifetime

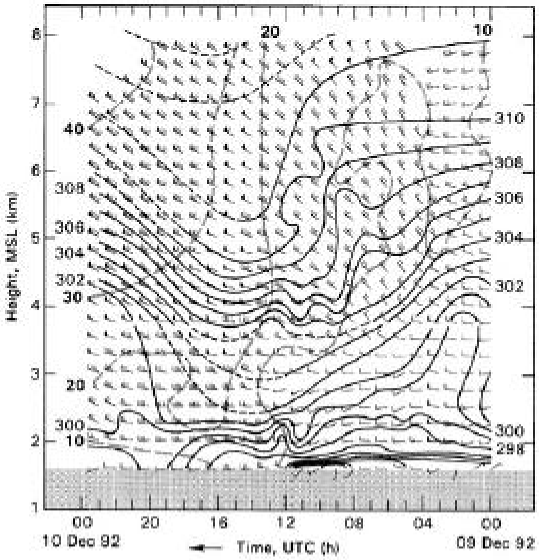


Justification

•Enables high vertical resolution profiling of tropospheric wind fields, with potential for cross-track horizontal resolution of 100-200 km in separate tracks or swath on either side of sub-orbital track

Top-Level Development Schedule

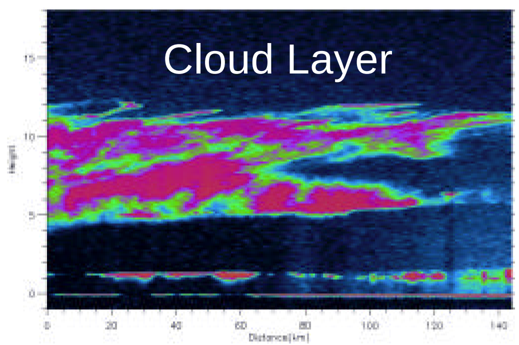
- Component development 2002
- Brassboard 2002-2003
- Engineering Model 2003-2004

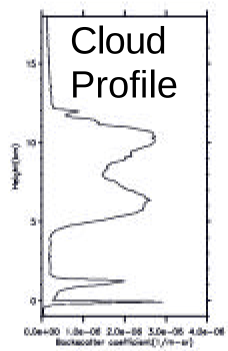


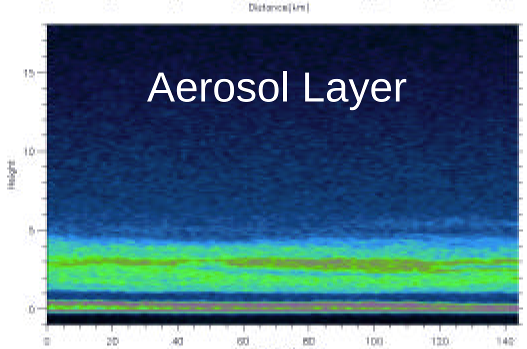
Development Plans for Cloud and Aerosol Laser Transmitter

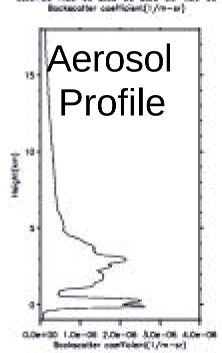
Laser Type

- Nd:YAG
  - Single-mode
  - Narrow frequency
- <5 pm linewidth
- > 100 Hz PRF,
- 5-50 Watts Output
- Conductive cooling
- 7% WPE
- 3-5 years lifetime









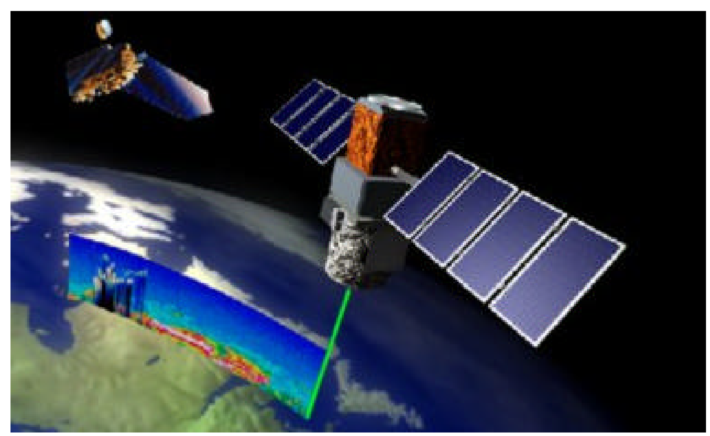
Justification

•Enables cross-track scanning backscatter lidar
  - Mapping cloud profiles
  - Mapping aerosol profiles

•Produces distributions with high vertical and horizontal resolution for clouds and aerosols of radiation forcing significance

Top-Level Development and Schedule

- Component development 2002-2003
- Brassboard 2003-2004
- Engineering Model 2004-2006



Workshop Summary Comments

- Most pressing need is support for brassboard and engineering model development of lasers for science-driven mission types
  - Risk reduction and reliability enhancement needed for future space lidars;
  - Leverage commercial technology development to extent possible;
  - Proposals for these developments require science requirement justification and accompanying lidar system performance modeling;
  - Improvements in realism of performance modeling require increased NASA investments in RTOP tasks addressing atmospheric measurements and characterization , and airborne instrument measurements.
- Establish/maintain NASA core competency in critical areas
  - Requires ongoing efforts to maintain critical personnel skills and modern laboratory facilities/equipment, coupled with vigorous recruitment of new talent in laser physics and engineering as well as e.g., contamination control, thermal design, radiation tolerances
  - Pump diode technology is a key requirement for which an inter-governmental action plan should be developed
- Fund specific technology needs which enable improved laser capabilities
  - Refer to listings from previous workshops

Further Comments on Laser Technology Development

- High-power, high-energy, space-based lasers are “one-of-a-kind”
  - Large non-recurring engineering costs and large R & D costs
  - NASA must leverage commercial technology to largest extend, but must develop in house capabilities to drive technology in directions unique to the civilian government sector
- Focused research towards enhancing laser efficiency and environmental robustness
- Commercial sector is increasingly uninterested in developing technology for U.S. government problems
- Targeted funding for space-based ““one-of-a-kind” high-energy lasers
- Directed core competency funding to NASA Centers engaged in laser research
- Integrated NASA strategy for developing component level and sub-system level technologies for future missions
- Foster technical alliance between NASA Centers, USAF, NOAA, DOE, NSF for the space-based laser technologies
- Develop, demonstrate and validate Engineering Model before mission award
- Parallel funding of core basic research, modeling, and laser materials development
- Yearly investment of $5 M towards space-based laser diode development, high damage threshold optics, conduction-cooled technologies, and radiation hardened component development
- Periodic review and assessment of laser technology plans and funding needs